PCT/AU99/00934

AUSTRALIA

AU 99 | 934

| REC'D 08 DEC 1999 | |
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09/830112

I, LEANNE MYNOTT, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PP6733 for a patent by CITR PTY LTD filed on 27 October 1998.

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# PROVISIONAL SPECIFICATION

Invention Title: "MANAGEMENT OF TERMINATIONS IN A COMMUNICATIONS NETWORK"

The invention is described in the following statement:

TITLE

## MANAGEMENT OF TERMINATIONS IN A COMMUNICATIONS NETWORK

FIELD OF THE INVENTION

This invention relates to the management of connections in a large scale heterogeneous communications network, such as those operated by telecommunications utility companies and utilised by different carriers and service providers. In particular the invention relates to a method and apparatus for selecting terminations for connections in a broadband network for customers requiring a communications service.

BACKGROUND TO THE INVENTION

The term "communications network" as used in the specification, is meant to encompass networks suitable for voice telephony and for data communications. Such communications networks may be suitable for switching and transporting voice, data, sound and/or image traffic which might otherwise be referred to as broadband or "multimedia" communications.

Existing communications networks are characterised by a number of transmission mediums using a variety of network technologies, protocols, software applications and equipment sourced from different vendors. Whilst much of the equipment includes management functions, such as monitoring, test and alarm features, the centralising, handling and controlling of network management functions in a complex multi-vendor environment is a significant problem.

A further problem in a heterogeneous network - which might include customer access technologies (ADSL, HFC), core network technologies (ATM, frame relay) and transmission technologies (SONET/SDH, WDM) - is that the management of end-to-end connections is typically conducted according to a lowest common denominator philosophy. The services provided by the network are limited to those able to be supported by the least capable equipment in the network. This philosophy is very ineffective in utilising the full capability of the diverse communications paths available in a network to meet particular service requirements of customers.

Conventional network management centres use several operation support systems (OSS) for optimising the allocation of resources in a communications network. Generally information on both the flow of communications traffic in the network and the functional capabilities provided by network switching elements, which together may be referred to as the 'network state', is accumulated at the network management centre. Typically information on the network state is maintained in a central database which must be periodically updated to reflect changes in the communications network. The database may be updated directly or by agent systems present in a distributed network. Accordingly, the network management centre can remotely monitor the network state for assessing performance levels, detection of equipment failure, rectification of circuit outages and network traffic.

A significant problem associated with a central network state database is the overheads which are imposed on the communications network in keeping the information current such that appropriate resource allocations decisions might be taken. This is sometimes referred to as the problem of "synchronising" the information in the network management database with the availability of network elements, their functional attributes and real time state. This problem is particularly acute with respect to the management of individual terminations, being a large scale undertaking which impacts on network connectivity.

<u>Glossary</u>

| | |
|---|---|
| AAD: | ATM access device |
| ADSL: | asymmetric digital subscriber loop |
| ATM: | asynchronous transfer mode |
| CMIP: | common management information protocol |
| CORBA: | common object request broker architecture |
| EMS: | element management system |
| HFC: | hybrid fibre-optic co-axial |
| NMS: | network management system |
| NTU: | network terminal unit |
| OSS: | operation support system |
| VPC: | virtual path connection |
| SDH: | synchronous digital hierarchy |

| | |
|---|---|
| SNMP: | simple network management protocol |
| SONET: | synchronous optical network |
| TCP/IP: | transmission control protocol / Internet protocol |
| TL/1: | interface protocol for network management |
| VCI: | virtual circuit identifier |
| VPI: | virtual path identifier |
| WDM: | wave division multiplexing |

## OBJECT OF THE INVENTION

It is an object of the present invention to provide a connection manager for selecting terminations for a predetermined path in a communications network that carries broadband traffic between two locations in the network which ameliorates or overcomes at least some of the problems associated with the prior art.

It is another object of the invention to provide a method for selecting terminations for a predetermined path in a communications network thereby contributing to cost effective routing of broadband traffic between two locations in the network.

Further objects will be evident from the following description.

## DISCLOSURE OF THE INVENTION

In one form, although it need not be the only or indeed the broadest form, the invention resides in a connection manager for selecting terminations from a plurality of terminations for paths available in a communications network for carrying broadband traffic, wherein the connection manager includes:

(a) a connection model that indicates functional features supported by each path in the network and locations of terminations for respective paths;

(b) an interface to control means which manage the feature specific functions of the terminations in the network; and

(c) processing means operative, in response to a request for termination of a predetermined path in the network between two locations, for identifying from the connection model in light of termination features required for the predetermined path, appropriate control means; whereby

(d) selection of individual terminations for said path is delegated to the identified control means, which delegated selection involves:

(i) determining whether an individual termination supporting the required features is available at the location; and

(ii) if more than one termination supporting the required features is available, adjudicating amongst equivalent terminations.

Preferably the functional features represented by the connection model include one or more of the following categories:

(i) communications protocol;

(ii) transmission rate;

(iii) availability of the path;

(iv) average error rate

(v) fault reporting requirements; and/or

(vi) physical location.

Preferably said plurality of terminations are assigned to termination groups in accordance with their termination role.

The role of a termination group may include location, physical configuration or functional features supported by the terminations in the group.

Most preferably, terminations are managed by a hierarchy of control means wherein the individual terminations are at the lowest level in said hierarchy.

If required, the terminations are grouped in accordance with the hierarchy of control means.

Suitably the delegated selection of individual terminations further includes traversing the hierarchy of control means to a control means managing individual terminations.

Preferably, adjudication amongst terminations is conducted by the control means on the basis of cost attributed to respective terminations.

In preference the control means report the identity of the individual termination at each of the two locations selected for the predetermined path.

Preferably said interface to control means includes network equipment adaptors co-located with network switching, transmission and/or terminal equipment.

In another form the invention resides in a method for selecting terminations for a predetermined path in a communications network for carrying broadband traffic, the method including the steps of:

(a) creating a connection model that indicates functional features supported by each path in the network and locations of terminations for respective paths;

(b) providing an interface to control means which manage the feature specific functions of the terminations in the network;

(c) identifying, in response to a request for termination of a predetermined path in the network between two locations, from the connection model in light of termination features required for the predetermined path, appropriate control means; and

(d) delegating selection of terminations for said path to the identified control means, whereby delegated selection involves:

(i) determining whether an individual termination supporting the required features is available at the location; and

(ii) if more than one termination supporting the desired features is available, adjudicating amongst equivalent terminations.

Preferably said plurality of terminations are assigned to termination groups in accordance with their termination role.

The role of a termination group may include location, physical configuration and functional features supported by the terminations in the group.

Most preferably, terminations are managed by a hierarchy of control means wherein the individual terminations are at the lowest level in said hierarchy.

Suitably the step of delegating selection of individual terminations further includes traversing the hierarchy of control means to a control means managing individual terminations.

Preferably, adjudication amongst terminations is conducted on the basis of cost attributed to respective terminations.

Preferably the method includes a further step wherein the control means report the identity of the individual termination at each of the two locations selected for the predetermined path.

The delegated selection suitably involves the following steps to traverse the hierarchy of control means, which steps are executed recursively:

(a) if a control means returns an individual termination,

  (i) then report the termination's identity to the connection manager;

(b) otherwise the control means,

  (i) delegates to a lower level control means in the hierarchy;

  (ii) compares available terminations; and

  (iii) returns lowest cost termination.

## BRIEF DETAILS OF THE DRAWINGS

To assist in understanding the invention preferred embodiments will now be described with reference to the following figures in which :

FIG 1 is a diagram of a heterogeneous communications network including a hierarchy of connection managers;

FIG. 2 is a diagram illustrating the structure of a connection manager of a first embodiment;

FIG. 3 is a diagram of a world view from the perspective of the abstract connection model of the first embodiment;

FIG. 4 is a diagram of a hierarchical tree structure of termination groups which may be present in a communications network; and

FIG. 5 is a diagram illustrating fragments of a network with a deployed connection manager enabling delegated selection of terminations.

## DETAILED DESCRIPTION OF THE DRAWINGS

The embodiment of the invention is described in the environment of a heterogeneous communications network 10 as illustrated in FIG. 1. The connection manager of the embodiment participates in the service activation and service assurance processes of large communications networks. The connection manager is suited to use in relation to broadband communications products which have significant complexity at the "Network Layer" (as defined by the ITU-T layered management model) - such as ATM, SDH, IP and bundled broadband products. The connection manager supports fault, configuration and security activities at the Network Layer and can cooperate with other systems performing these functions for subsets of the communications network. The connection manager of the

embodiment resides in a network management layer 30 between the service layer 20 and the network element layer 40.

The service layer 20 typically includes service order systems 21 which institute the creation of new connections and facilitates the query, modification and deletion of existing connections, service assurance systems 22 which facilitate the test and repair of existing connections and pre-sales systems 23 which support pre-sales activities including enquiries regarding available connection characteristics, connection cost and time frame. Examples of service layer systems include service order, customer network management (CNM), test and repair or wholesale gateway.

The network element layer 40 typically includes the hardware for providing network services such as switching or transmission, for example ADSL/HFC customer access technologies 41, ATM core network broadband technologies 42, and transport technologies 43 such as SONET/SDH or WDM. The network element hardware may be conceptually considered to reside in different "domains" and is typically also proprietary in nature. Accordingly, the network element hardware generally uses proprietary or compatible network element managers which act as proxies for many of the network elements.

Examples of network element managers are EMS systems 44 and 45 for the ADSL/HFC hardware, the NMS 46 for the ATM core hardware and the vendor specific NMS 47, 48 for the transport domain. Although the network element managers manage many network elements, they expose each network element as an individual entity. Thus in other embodiments, the connection manager may interface directly to the network elements.

The network management layer 30 of the embodiment illustrates the flexibility of the connection manager. A first connection manager 31 is interfaced to the EMS systems 44 and 45 for managing the customer access domain 40A. The functional flexibility of the connection manager arises from its ability to manage the functionally different requirements of the switch matrix EMS 44 and the AAD EMS 45. A second connection manager 32 manages the core domain 40C and a third connection manager 33 is interfaced to the vendor NMS systems 47 and 48 in the transport domain 40T. The transport domain illustrates the ability of the connection manager to handle disparate vendor equipment. The connection managers include interfaces which communicate using the CMIP, SNMP, TL/1 or proprietary protocols as

required. These interfaces may be adapted to suit particular vendors' equipment, current or future.

A fourth connection manager 34 is interfaced with the three domain connection managers 31, 32 and 33 for the purpose of cross-domain connection management. The cross-domain manager 34 level accepts end-to-end connection instructions for the entire network, it determines which paths through the underlying networks are available and issues connection instructions to the domain connection managers as appropriate. The connection task is thus delegated to the appropriate domain connection managers. Any network events - including faults, congestion and usage - that effect connections, are reported back to the service layer enabling immediate identification of the customer and the service being provided.

Although shown as four separate managers, the network management layer 30 may be viewed as undertaking the overall connection management function for the network, with the cross-domain connection and domain connection being managed at different levels. Thus the network wide connection requirement is simplified step by step so that each level of connection management can be optimised to manage the portions of the network under its control. However, the separate connection managers illustrate the distributed nature of a network wide connection manager 35 which may be geographically distributed across a large number of sites and network operations centres.

Network Models

The connection manager provides flexible network modelling tools for representing a service provider or network owner's view of broadband connections. The key concepts for these representations are:

(i) "paths" which represent the owner's view of a connection, such as ATM PVC;

(ii) "terminations" where the path is manifest outside of a network, such as an ATM VPI, VCI and cable, or a customer NTU; and

(iii) "features" which are the external selectable characteristics of the path visible at its terminations, such as quality of service, bit rate or path diversity.

Conceptually a path can negotiate many network elements and protocols, such as end-to-end SDH connections implemented using SDH switches and WDM transmission.

Connection Manager Structure

The structure of the connection manager 35 of the embodiment is described in relation to FIG. 2, as it might be deployed in relation to a particular network. A connection model 36 is used to represent the network and its services, which model may be implemented by the core software 37. Network adapters 38 are provided to interface with network elements, EMS or other NMS. Service adaptors 39 are provided to interface to existing service and test OSS, whilst peer OSS adaptors 50 interface fault, security, accounting and like support systems.

The connection manager 35 supports several fundamental operations relating to the life cycle of a path. The network owner may instruct that a path be *reserved*, *created* or *changed*, which results in the automatic selection, allocation and configuration of appropriate network equipment to implement a connection with the specified features between specified terminations. An *override* operation gives the owner the ability to influence the selection, whilst a *remove* operation frees the allocated network equipment.

The connection manager allows the determination of which features are supported, in what combinations and at what localities in the network. Terminations and paths may be searched and listed, and the termination which best supports a given set of features in a locality suggested by the connection manager. A *preview* operation facilitates - without actual performance - prediction of the validity of a life cycle operation, the amount of resource that the path will require, and the time required to execute the operation.

In relation to network assurance, the connection manager includes *test* operations to automatically verify the implementation or operation of a connection, invoking network test hardware as necessary. The *repair* operations rectify faults, either internally or by delegating to some other OSS or operator. The connection manager performs alarm derivation and correlation, by taking equipment oriented alarms and producing path oriented alarms. The correlation can reflect the network topology, fault severity and network operational rules.

The connection manager 35 of the embodiment preferably uses a CORBA IIOP architecture to interface to both the service layer and the network layer. The service layer interface and the network model can be adapted to present some standard data models, such as ETSI 600-653 or ATM Forum M4, or adapted to existing service layer interfaces. All connection manager objects can be annotated with the names and identifiers required by external systems, for example customer circuit identifiers. A shell adaptor is also provided to minimise the skill and work needed to interface with an SNMP, TL/1 or CMIS system on the network side.

The core software 37 of the connection manager allows for plug-ins 51 in order to provide for coded replacements to overcome specific limitations to core algorithms.

The connection manager is a high-availability system supporting on-line changes to configuration with back-out, on-line database backup, replicated databases and redundant hardware. Depending on configuration, the connection manager will support 10,000 transactions per hour on one mid-range server machine (for example a Hewlett-Packard "J-class" server). This typically corresponds to a network with 50 million installed paths with a typical operational latency is 0.3 seconds. The connection manager will typically process 10 network alarms per second on one mid-range server. This typically corresponds to 1 million to 5 million installed paths. A low level event correlation system can be provided to smooth out alarm storms.

One connection manager installation can be distributed, as indicated above, over a number of server machines. A distributed installation on up to 10 machines would be typical, as transaction and alarm processing scale approximately linearly over this range. Such installation can suitably support HP UX or Solaris on SUN Sparc, Microsoft's NT on Intel or PA-RISC operating systems.

FIG. 3 shows a view of the world from the perspective of a connection model, considered in the abstract. The connection model is a framework for describing communications systems involving connections. In particular, the abstract connection model 52 of the embodiment is a distributed, object oriented way of representing the state and operations required to manage the network layer 30 of a broadband communications network. The service layer 20 is effectively the driver

for the connection model in that providing function to the service layer is the role of the connection model.

In order to address requests from the service layer the connection model delegates to either the network element layer 40 - in the form of either network elements 53 or network element managers 54 or other providers at the network layer - for example other connection managers 55 or network service provider (NSP) 56. The choices involved in performing delegation include: (a) to which subordinates are functions delegated? (b) how are super-functions mapped to subordinates? (c) what is the sequencing of subordinate operations? (d) what actions occur when a subordinate operation fails? and (e) how are changes in the network configuration and network engineering policies reflected?

The abstract connection model must be instantiated, with the instantiation depending on:

(i) the particular networking technology employed by the network owner;

(ii) the network owner's engineering rules; and

(iii) the network owner's service level requirements.

It is the model's instantiation 36 that gives meaning to the components of the model, such as path, feature and termination. When a connection model is instantiated, each of the abstract concepts that it presents will have a precise meaning. That meaning is conveyed by the model's descriptive text, rather than the syntax or semantics of the model's interfaces. Furthermore, a model instantiation will have objects instantiated against it which objects will conform to both the abstract connection model and the instantiated model. This development process may be contrasted with a traditional approach, wherein objects are instantiated against one fixed model.

The development of a connection manager application normally includes the following three stages:

(a) Network analysis and design - the focus at this stage is to define the architecture of the network to be managed and to analyse the characteristics of each component of the network.

(b) Connection manager installation - the focus of this stage is to use the mechanisms supported by the core software to specify the rules for how the network should be managed. The installation is the outcome of this stage.

(c) Run time - once a connection management system is installed, paths can be created through the network to provide communications services.

Basic Concepts

The basic concepts for connection management used by the connection model are the path-termination-feature concepts introduced briefly above. A *feature* is a characteristic of service manifest to a customer, for example: ATM protocol, 64 kb/s data rate and unavailability for less than 1 minute/year. Features are installed on connections, which often requires feature values. The feature Maximum Bit Rate has a value specifying what the maximum bit rate is, for example Maximum Bit Rate = 256 kb/s. A feature with values applied to a connection is referred to as an *installed feature*.

A *path* is provided by a network and is fully characterised by the installed features of the path (the *path features*), a set of *terminations* exposed to the client and a set of installed features for each termination (the *termination features*). A *network* represents the ability to manage paths and is used to create new paths and list existing paths. Paths are always totally contained within exactly one network.

Networks manifest themselves in terminations, and terminations are contained within one network. A termination can participate in a finite number of paths, typically one, but potentially more. A path in a network will have one or more (usually two) terminations. Single termination paths may represent loop-back, multiple terminations may represent multiple drop (for example CSMA) or a closed user group (for example a voice private network). Paths may share terminations, this may express a multi-serving capability (such as the set of customers using a billing server).

A network will generally have many terminations, for example broadband networks having 100,000 physical terminations and $2^{40}$ addressable logical terminations are not considered large. Managing each termination individually is a large scale job, because each termination impacts on network connectivity, cost and feature validity. Some terminations generally have a great deal in common and are easily assigned to groups where each termination in a group has a highly regular pattern of connection and the same impact on cost and feature validity.

Connection Model

The connection manager 35 presents an architecture for assembling a working network management system. The core software 37 provides an abstract connection model which can be configured to reflect the characteristics of the particular network equipment deployed by the network owner. The operative connection model 36 can also reflect the business and engineering policies of the service provider or network owner, in other words, the knowledge that a human operator would apply if they were performing the connection manager functions manually. The core software 37 assumes that the interface to the network supports the connection model 36, preferably expressed in CORBA.

The network adaptors 38 are constructed from shells, which include code fragments, applications program interfaces and libraries, to integrate with any contemporary network management interface. The shell adaptors are designed to inter-work with stack products, such as those vended by Vertel and Hewlett-Packard, in order to provide simple interfaces into complex protocols such as CMIS or TL/1.

The service adaptors 39 provide an interface between the network's service management layer OSS. Existing operation support systems generally have a proprietary interface, although there are some emerging standards including the US Federal Communications Commission's "Gateway". Printed paper or a character terminal are common interfaces. The deployed connection manager 35 preferably has an adaptor to automate the interface between the service management layer and the core software 37.

The peer OSS adaptors 50 may be provided to allow the connection manager to inter-work with other network support systems in the network management layer, such as the alarm and security OSS. The core software 37 has certain in-built algorithms that determine its behaviour. These algorithms are configurable, allowing the network owner or systems integrator to tailor the core software for their specific needs. However, there are limitations to the amount of flexibility that can be achieved through configuration. Accordingly the connection manager 35 allows for use of plug-ins 51, which are coded replacements for selected core algorithms.

Distributed Object Model

As the connection manager is a network layer manager, it is only concerned with modelling network-level concepts. The first network level concept is "connection". The connection model 36 of the embodiment is a distributed object model, preferably expressed in CORBA interface definition language (IDL). In accordance with the concepts introduced earlier, there are three types of objects, namely:

(i) path objects that represent connections;

(ii) termination objects that represent where the connections are physically manifest; and

(iii) network objects which are the fabric that can create connections.

Network Objects

The network object is a container of path objects and termination objects. Network objects form a hierarchy, where some network objects are superior to others. Network objects will typically form a strict containment hierarchy, though the connection manager allows any non-cyclic structure. Network objects can represent: individual network element instances, groups of network elements organized by some owner determined criteria, such as geographic domains or functional domains; sub-networks that are managed by some other NMS, such as a vendor NMS; cross-domain networks that aggregate several domain network objects, such as those identified 40A(ccess), 40C(ore) and 40T(ransport) in FIG. 1.

Network objects support the following operations: listing the capabilities of the network object; listing the characteristics of the paths that the network objects can create; creating paths having specified terminations and features; previewing path creation; searching for paths, terminations and sub-networks having specified characteristics. Network objects may be configured as follows: assigning identity, description and meaning; defining the relationships between the network objects (for example, a containment tree structure); defining the connections between subordinate network objects; and the characteristics of the paths they can create. The connection manager provides no specific operations for creating network objects, establishing relationships between network objects or creating connections between subordinate network objects.

Path Objects

Path objects represent the connections formed by network objects. They correspond to some real-world connection concept. This could be for example:

(i) a physical connection, such as a bearer distribution frame;

(ii) a switched connection, such as an ATM virtual circuit; or

(iii) some abstract relationship, such as the relationship between a customer and their Internet service provider (ISP).

A path object is always contained within one network object. When network objects form a hierarchy, a network object may implement that path by delegating portions of the implementation to sub-paths in its subordinate networks. Paths are characterised by terminations and features. Terminations describe where the path is manifest, features describe externally visible characteristics. A path generally has two terminations.

A feature has a name and optionally a value. The value have can have arbitrarily complex structure. A feature may be able to take one of a finite number of values. Features are applied to either the path itself, or terminations on the path. This permits termination-specific features to be modelled - as required for asymmetrical paths. It is common for features to interact - that is the existence of one feature affects the ability of a path to support another feature. The core software supports a feature interaction connection model which allows the modelling of optional, compulsory, mutually exclusive and invalid combinations of features.

Paths support life-cycle type operations. This allows for several levels of completeness of the path's implementation. The levels of implementation are:

(a) *design* - The path consumes no resources, other than those minimally needed to record its characteristics. Design state paths need not obey any rules.

(b) *reserve* - The path is fully implemented, except the last step which would enable service.

(c) *installed* - The path is implemented into the equipment to enable service.

(d) *deleted* - The path no longer exists, but the memory of it is kept for audit purposes.

Paths have a cost, which represents the amount of resource required to implement this path. The cost allows a client to rationally choose between several candidate paths, each of which is capable of supporting their needs. Path objects support the following operations: deletion; changing the features, terminations or implementation completeness; preview operations for the above; and listing the path attributes. Path objects themselves do not have any configuration. However the containing network objects may be configured for the following path-related functions: the list of features that could apply to a path in the network along with the feature interaction and locality rules.

Termination Objects

Termination objects represent where path objects are (or may be) manifest. They correspond to some real-world concept for example: a physical termination, such as a cable; one channel multiplexed over some bearer such as an ATM virtual circuit or SDH container; a grouping of multiplexed channels, such as an ATM virtual path. A termination object is contained within one network object. A network may express an effectively infinite number of terminations, for example an ATM network may model each VPI or VCI as a termination. Even coarser grained modelling than the ATM example will have large numbers of terminations. To allow these to be easily managed, the connection manager typically supports the grouping of terminations into "termination groups".

Termination Groups

The connection model preferably manages the commonality of terminations through the use of termination groups. In the embodiment, the termination groups of one network object preferably form a containment tree 60, such as illustrated in FIG. 4. There is a root node 61 that includes all termination groups that otherwise have no container. The upper layers of the tree are generally abstract groupings, typically based on physical location, such as city 62 or central office building and switching equipment 63. The lower layers of the tree are typically more concrete, such as interface card 64 or cable 65. The leaves of the tree are the lowest level of modelled termination, such as cable, IP address 66, virtual channel 67, or similar technical constructs.

The use of termination groups for equipment such as switch N2 is as follows:

- all ATM VCIs appear as terminations in VPI termination group 2;

- the VPIs that appear in the same cable are the CABLE 2 group;
- the cables terminating on a particular card are grouped on CARD 2; and
- finally into the group for switching stage N2.

The connection manager makes no clear distinction between termination and termination group - termination groups appear higher in the tree and individual terminations occur toward the leaves. The network object's state what levels in the tree it is prepared to establish connections between - typically this may only be the leaf nodes. The meaning of terminations, and the structure of termination groups is specified by configuration of the core software.

Each termination preferably exposes to clients a cost for supporting paths with particular features. This allows clients to make a rational choice between several possible terminations, each of which could meet their needs. The meaning of cost is specified by the core software configuration. The cost values may also be specified by the core, however it would be common for a deployment to reflect values from the network equipment, such as congestion (via the equipment adaptors).

Termination objects support the following operations: describe the termination; describe the termination group structure (actually an operation on the containing network); navigate through the termination group structure; and find, within a termination group, the lowest cost free termination capable of supporting a particular set of features. As there are a huge number of terminations in a typical network, most deployments will configure terminations at the level of a termination group. The characteristics of the individual terminations will be derived from the network equipment adaptors. Termination group objects support the following configuration: the termination group structure and (optionally) the cost of members of the group.

Termination Roles

Each termination (and any corresponding termination group) has a purpose which is referred to as a "termination role". Examples of termination roles 70 are indicated on FIG. 4 and may include location 71, switch 72, card 73, cable 74, IP Address 75, ATM VPI 76 and ATM VCI 77. There is no specific requirement for a termination group to have an enumerable number of members or a fixed number of members, as the members may reflect some dynamic characteristic of a network.

In a typical hierarchy of termination groups, termination roles tend to reflect location at upper levels and tend to merge with function at lower levels. With reference to FIG. 4, a request for a free termination in the termination group "Sydney" with role "ATM VPI" to the connection manager could return for example:

"Sydney.North.SwitchN2.Card2.Cable2.1"

The connection manager can use whatever level of termination grouping is desired by the service provider or network owner. Using the above example, the connection manager may allocate paths at the interface card level 64, delegate interconnection to the cable level 65, whilst the validity of features could be handled at the switch level 63. The levels may be mixed, for example costs may be specified at the card and cable levels. In some instances the termination group may correspond to a customer network terminal unit (NTU). It is important that the scheme for termination groups selected by the network owner or communications engineer is not ambiguous for any individual termination.

Network Interface

The connection manager can inter-work with equipment in the network in a number of different modes. The connection manager can be interfaced direct to a network element, typically via SNMP, TL/1 or CMIS systems; it can be interfaced into a vendor's element manager, where it sees the individual network elements; it can be interfaced into a vendor's domain manager, where the domain manager is used to establish sub-paths in that domain or it can be interfaced into another network owner's wholesale network. The connection manager uses a published CORBA IIOP interface to the network to expose the life-cycle, model, state, search and sub-function operations described above on page 10. To deploy the connection manager, it is usually necessary to provide a network equipment adaptor from the IIOP interface to whatever interface the network layer presents.

Although it is possible to build a fully functional adaptor, it is preferable to build a minimal adaptor. A minimal adaptor does not implement any path life cycle operations (other than create and delete), *reserved* and *design* installation states, atomic transaction semantics, operation retry and error recovery, complex cost models, feature interaction, feature locality, preview operations or override operations. Accordingly, a minimal adaptor places much of the burden of network interfacing onto the connection manager core software.

Example

In order to explain the selection of terminations in accordance with a preferred system and method of the invention, reference is made to the network fragments illustrated in FIG. 5 in conjunction with the diagram illustrating the termination groups in FIG. 4. FIG. 5 shows the equipment associated with switch N2 and switch E2 which include the respective adaptors in North Sydney and East Melbourne, along with the interconnections to a connection manager located at a telecommunications company's national network management centre. In the example, a client requests an ATM virtual channel between North Sydney and East Melbourne with features maximum bit rate 1.5Mbps and unavailable less than 4 minutes per year, which results in the connection manager allocating a path which is routed from the North Sydney sub-network (N), over the Central Sydney sub-network (C), over the Canberra network, and then to the East Melbourne sub-network (E).

For ease of discussion, the connection manager 35 is illustrated as a single entity in FIG.5, although it should be appreciated it is generally implemented in a distributed fashion over a number of computer sites as discussed above (such as capital city management sites at Sydney and Melbourne). In response to the request for termination of the path between the North Sydney and East Melbourne locations with termination features for supporting an ATM virtual channel, the processor 41 identifies from connection model 36 the termination group North corresponding to the North Sydney exchange 80 and the termination group East corresponding to the East Melbourne exchange 90.

In accordance with a preferred method for selecting terminations, the connection manager 35 delegates selection of a suitable termination at North Sydney to the switch manager 81, by communicating with network adaptor 44 interfacing the switch manager to a CORBA compliant virtual bus 42. The switch manager 81, which controls operation of each of the switches N1, N2 and N3, determines that only termination group N2 associated with the respective switch supports the functional features required for termination of the ATM channel. Accordingly selection of terminations from within termination group N2 is delegated to the ATM port manager 82, via a second network adaptor 43.

The ATM port manager 82 controls allocation of ATM ports available on the cables attached to interface cards 83 for switch N2. Thus the port manager is associated with the termination groups having the termination roles card 73, cable 74 and ATM virtual port (VPI) 76 and channel (VCI) 77. The port manager 82 searches through the termination groups until the lowest cost "leaf" or individual termination, namely the ATM virtual channel identified as "Sydney.North. N2.Card2.Cable2.2.1", is returned to the connection manager. Suitably, the recursive search algorithm employed may be represented in the following pseudo-code:

```
if you are a leaf termination,
then
        return self
else
        pass to lower level terminations
        compare returned results
        return lowest cost termination
```

The connection manager also initially delegates selection of a termination at East Melbourne to switch manager 91, by communicating with network adaptor 45 interfacing the switch manager to the CORBA compliant virtual bus 42. The switch manager 91, which controls operation of each of the switches E1 and E2, determines that both termination groups E1 and E2 associated with the respective switch have the functional features required for termination of the ATM channel. However, E1 has a much lower cost for the particular feature of 1.5Mbps bit rate. Accordingly selection of terminations from within termination group E1 is delegated to the ATM port manager 92, via a second network adaptor 46.

The delegation process may be repeated by the connection manager 35 for each of the intermediate sub-paths over the central Sydney and Canberra networks, in the case that the sub-paths require termination.

Summary

The connection manager of the invention operates at several levels. The cross-domain management level can accept end-to-end connection instructions across an entire network, determines the path through the underlying networks

available to it, delegating the connection task to a number of network domain connection management layers. A network domain connection manager is cognisant of the termination roles of relevant termination groups, but delegates the selection of individual terminations to subordinate control systems managing feature specific functions. The connection manager need not keep track of information about the availability of network elements and the real time state and functionality of associated individual terminations, thereby reducing management information flows.

By automating the routing and configuration of connections across complex networks, the connection manager substantially reduces the need for manual management at the network and element levels. The real time state of the network is determined dynamically as needed, ameliorating the onerous requirement for synchronising a central network management database. Connections can be provisioned in real time and the connection manager will scale to process increasing volumes of new connections as broadband communications networks grow.

The approach to object oriented modelling in the connection manager, wherein the abstract connection model is differentiated from the connection model instantiations result in a high degree of reuse of clients and servers. This approach also allows for, but does not enforce, very flexible client and server implementations, which can match a rapidly changing business scenario.

Throughout the specification the aim has been to describe the preferred embodiments of the invention without limiting the invention to any one embodiment or specific collection of features.

Dated this Twenty-Seventh day of October 1998

**CiTR Pty Ltd**

by its Patent Attorneys

FISHER ADAMS KELLY

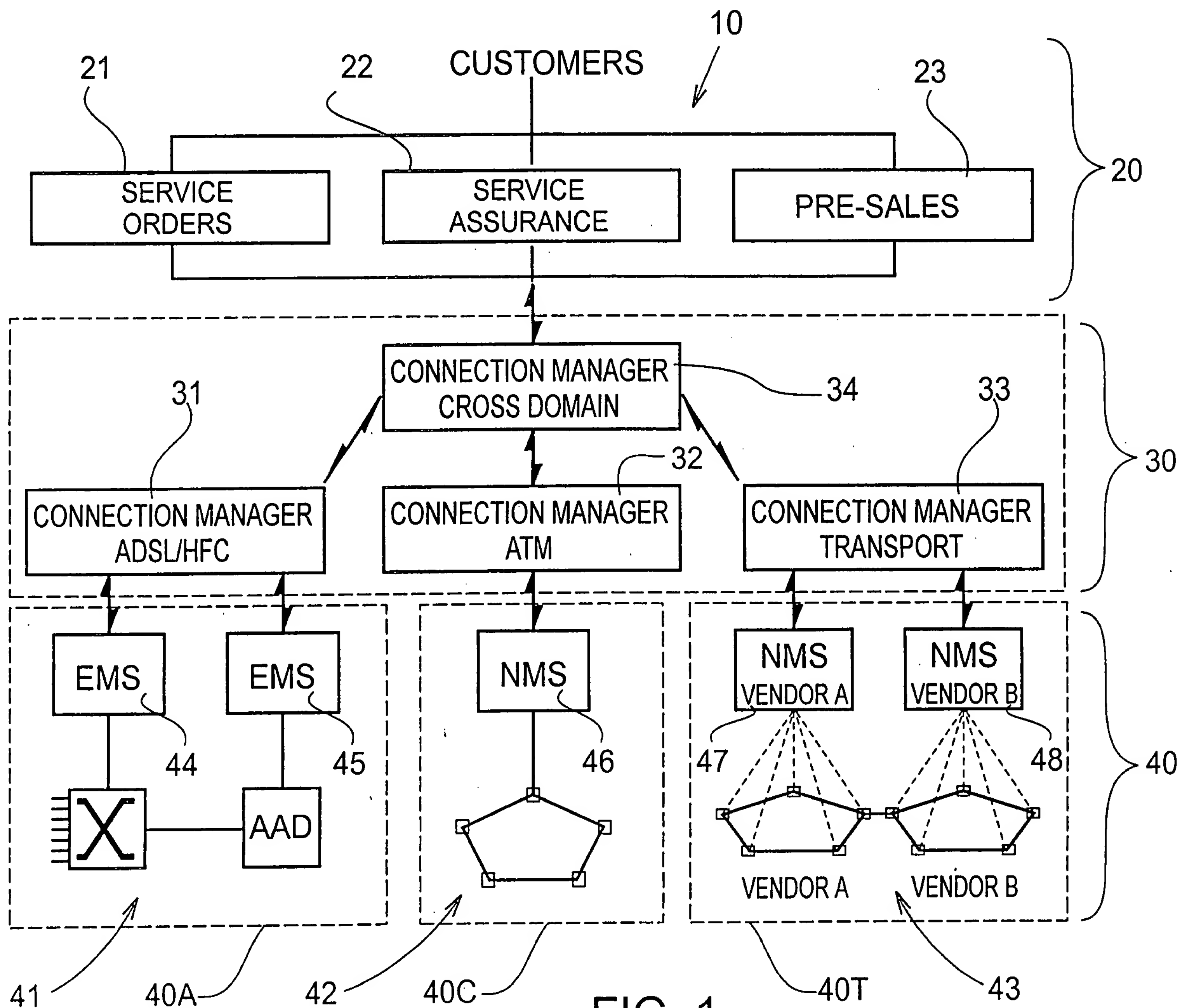

10
CUSTOMERS
21
22
23
SERVICE ORDERS
SERVICE ASSURANCE
PRE-SALES
20
CONNECTION MANAGER CROSS DOMAIN
34
31
33
32
CONNECTION MANAGER ADSL/HFC
CONNECTION MANAGER ATM
CONNECTION MANAGER TRANSPORT
30
EMS
EMS
NMS
NMS VENDOR A
NMS VENDOR B
44
45
46
47
48
AAD
VENDOR A
VENDOR B
40
41
40A
42
40C
40T
43

FIG. 1

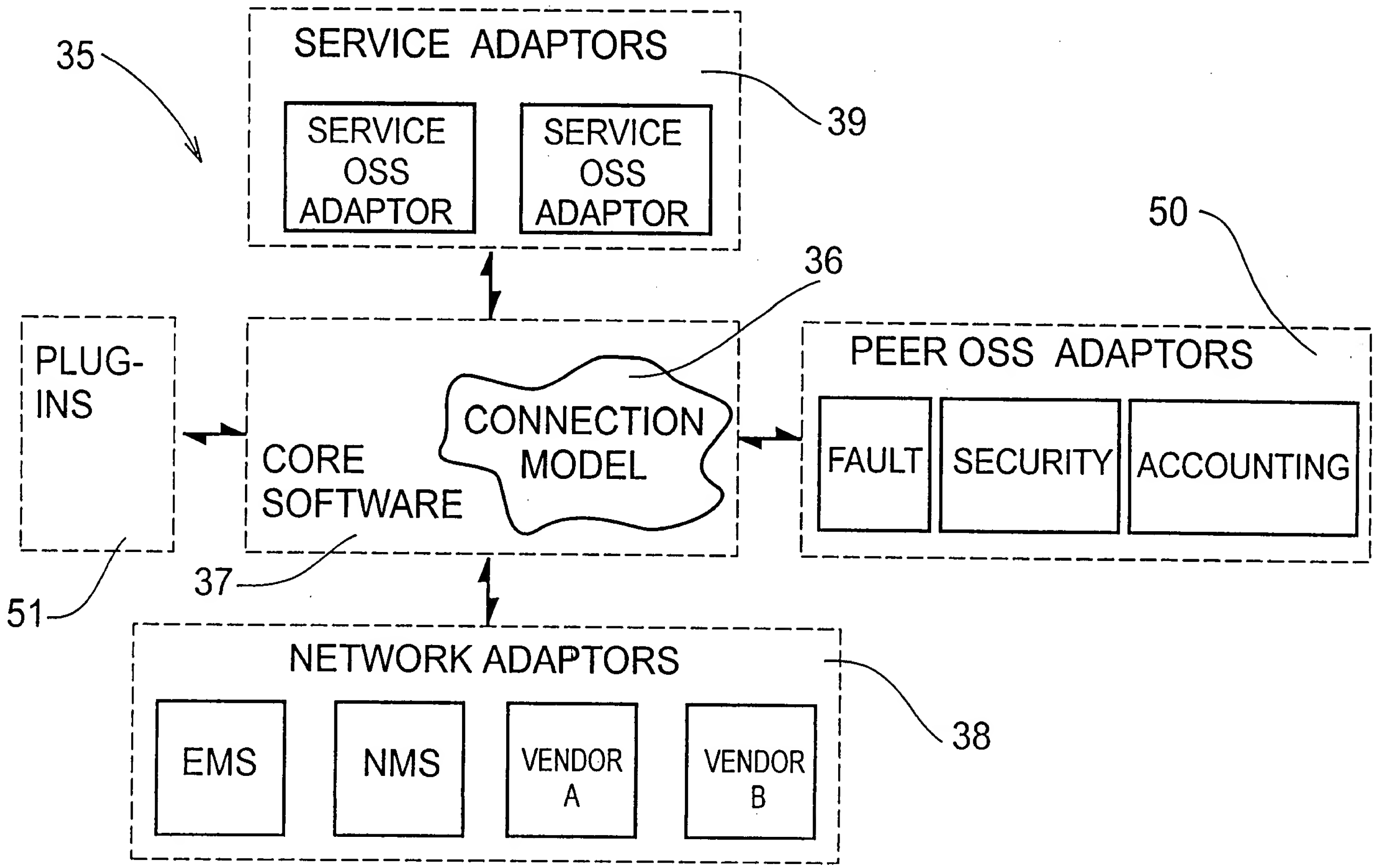

35
SERVICE ADAPTORS
SERVICE OSS ADAPTOR
SERVICE OSS ADAPTOR
39
50
36
PLUG-INS
CORE SOFTWARE
CONNECTION MODEL
PEER OSS ADAPTORS
FAULT
SECURITY
ACCOUNTING
37
51
NETWORK ADAPTORS
EMS
NMS
VENDOR A
VENDOR B
38

FIG. 2

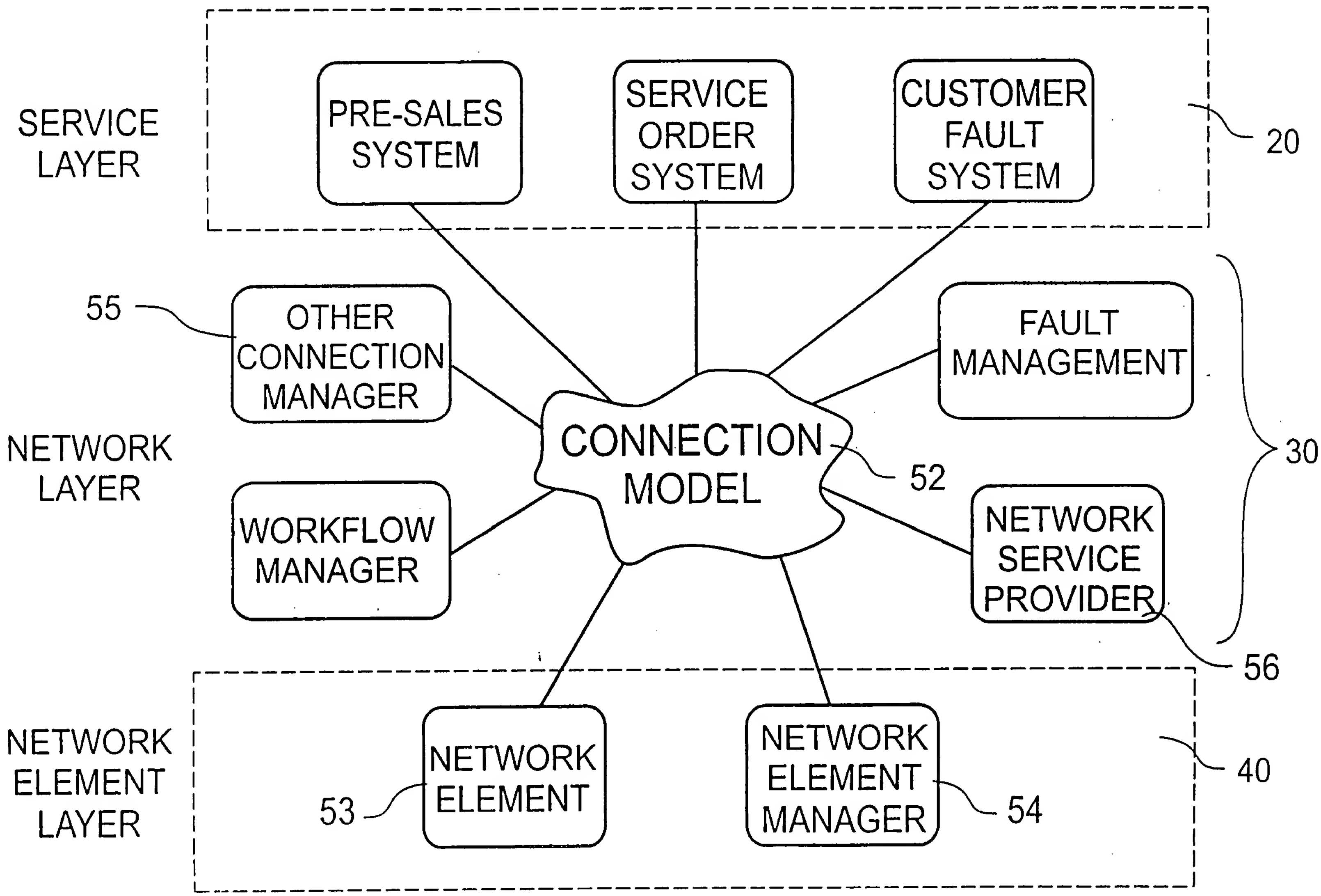
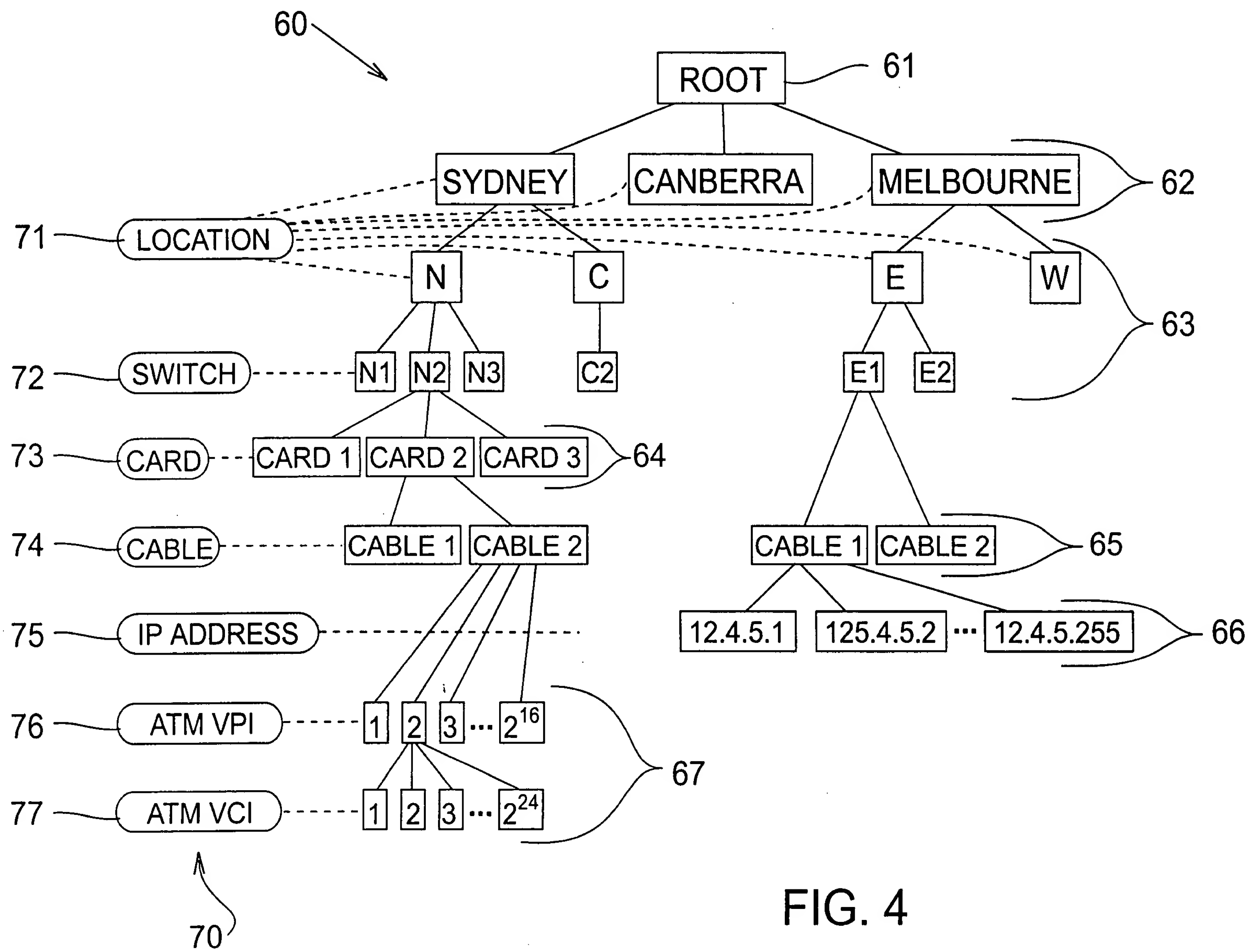

SERVICE LAYER
PRE-SALES SYSTEM
SERVICE ORDER SYSTEM
CUSTOMER FAULT SYSTEM
20
55
OTHER CONNECTION MANAGER
FAULT MANAGEMENT
NETWORK LAYER
CONNECTION MODEL
52
30
WORKFLOW MANAGER
NETWORK SERVICE PROVIDER
56
NETWORK ELEMENT LAYER
NETWORK ELEMENT
53
NETWORK ELEMENT MANAGER
54
40

FIG. 3



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ROOT
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SYDNEY
CANBERRA
MELBOURNE
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LOCATION
N
C
E
W
63
72
SWITCH
N1
N2
N3
C2
E1
E2
73
CARD
CARD 1
CARD 2
CARD 3
64
74
CABLE
CABLE 1
CABLE 2
CABLE 1
CABLE 2
65
75
IP ADDRESS
12.4.5.1
125.4.5.2
12.4.5.255
66
76
ATM VPI
1
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3
$2^{16}$
67
77
ATM VCI
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3
$2^{24}$
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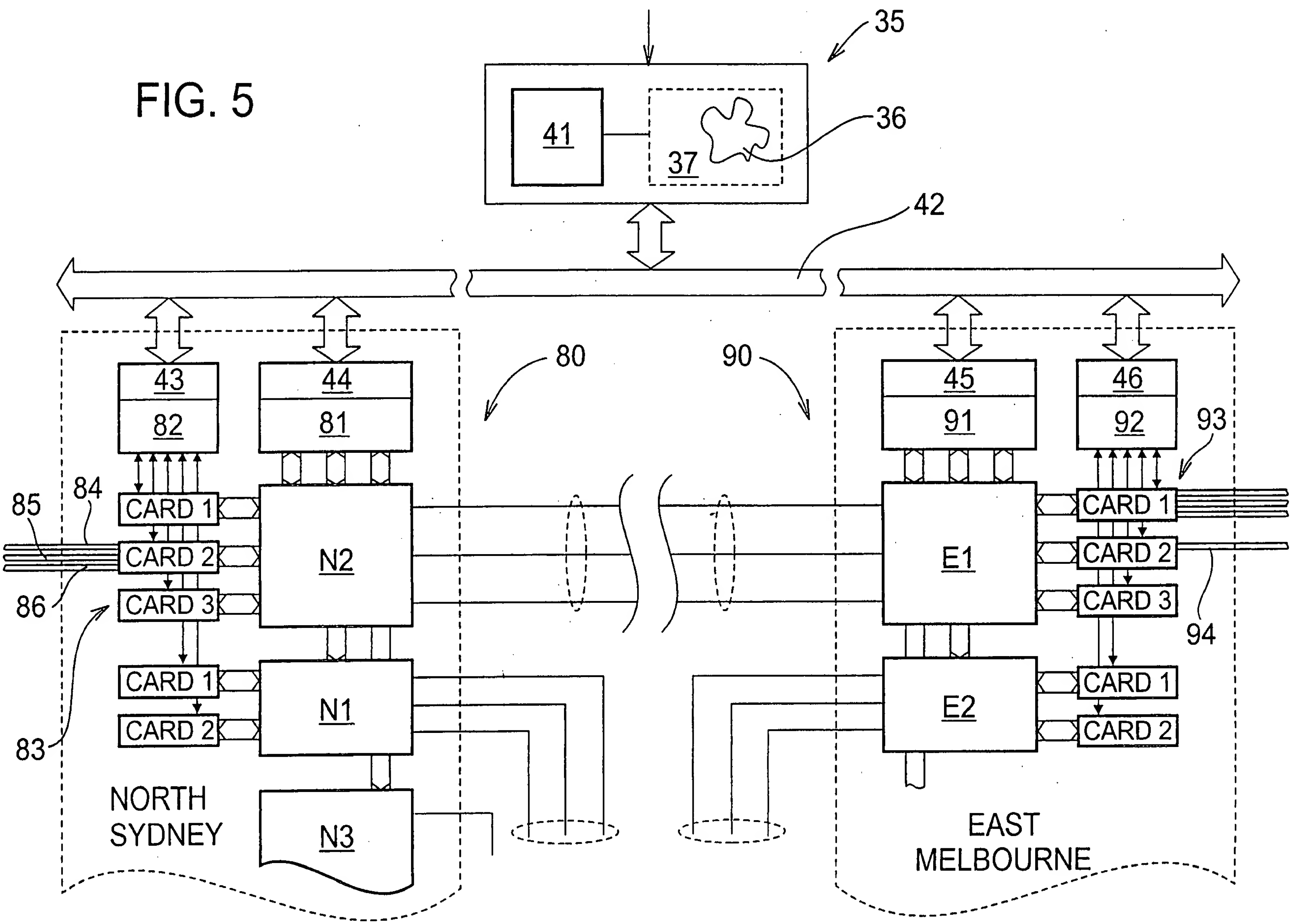
FIG. 4

FIG. 5



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CARD 1
CARD 2
CARD 3
CARD 1
CARD 2
N2
N1
N3
E1
E2
CARD 1
CARD 2
CARD 3
CARD 1
CARD 2
NORTH
SYDNEY
EAST
MELBOURNE